

# New optical spectra and general discussion on the nature of ULX's

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**Abstract.** We present spectroscopic observations of three Ultra Luminous X-ray sources (ULX's). Two of them are very close to the active galaxy NGC 720 and the other is near NGC 1073. The two around NGC 720 turn out to be quasars at  $z=0.964$  and  $z=2.216$ , the one near NGC 1073 seems to be associated to an HII region at the redshift of NGC 1073. We concentrate our analysis on the two quasars and analyze them in conjunction with a set of 20 additional X-ray sources close to nearby galaxies which also fit the criteria of ULX's and which also have been identified as quasars of medium to high redshift. This sample shows an unusually large fraction of rare BL Lac type objects. The high redshifts of these ULX's and their close proximity to their low redshift, supposedly parent galaxies is a surprising result in the light of standard models. We describe the main properties of each of these objects and their parent galaxy, and briefly discuss possible interpretations.

**Key words.** galaxies:active - quasars:general - X-rays:galaxies

## 1. Introduction

Numerous X-ray sources have been found in the central regions of nearby galaxies such as M 31 and successfully attributed to the presence of X-ray binary stars (e.g. Supper et al. 1997). A number of objects with much greater luminosities in the range  $L_X = 10^{39}$  to  $10^{41}$  erg s<sup>-1</sup> have also been found in nearby galaxies. In that case they are designated “Ultra Luminous X-ray sources” (ULX's). It has been proposed that they are exceptionally massive black hole binaries. If, however, at the distance of the parent galaxy a source has an X-ray luminosity exceeding about  $L_X = 10^{38.5}$  erg s<sup>-1</sup>, it needs to be more massive than a normal stable star (Pakull & Mirioni 2002 quote an Eddington limit as the upper bound on the luminosity of an accreting star as  $L_X = 10^{38.1} M/M_\odot$  erg s<sup>-1</sup> and Foschini et al. (2002a) quote  $L_X = 10^{38.3}$  erg s<sup>-1</sup> as the most luminous X-ray binaries in M 31). Other explanations have been proposed in terms of black holes in globular clusters (Angelini et al. 2001), or associations with HII regions (Roberts et al. 2003, Pakull & Mirioni 2002, Wang 2002, Gao et al. 2003). Alternative explanations have been proposed in terms of non-isotropic emission of the radiation (King et al. 2001; K rding et al. 2002). But, as dis-

cussed here, an important fraction of the ULX's which have been so far spectroscopically observed have higher redshift than the parent galaxy. So currently, the nature of these objects remains unexplained, and it is necessary to reexamine the assumption that they are physically associated with the galaxies in which they are found.

The most extensive catalog of ULX's is the one presented by Colbert & Ptak 2002 (CP02 hereafter) in which 87 ULX's in the near field of 54 RC3 galaxies with  $cz \leq 5000$  km s<sup>-1</sup> are compiled. However, these authors have filtered out known quasars and X-ray supernova. We think this is unjustified until the true nature of the ULXs become clear. In this paper we do not remove such objects, use only the  $L_X$  criterion to define ULX objects and change slightly the range in X-luminosity to define ULXs,  $L_X \geq 10^{38.5}$  erg s<sup>-1</sup>. To disentangle the nature of these objects it is necessary to find their possible optical counterparts and identify their characteristic optical spectral features. However, this is not an easy task (see Foschini et al. 2002b) due to the uncertainties in the X-ray coordinates and the faintness of many of these objects. In this paper we present the optical identification and spectroscopic observations of three ULX's, two of them (IXO1 and IXO2 according to the notation used in CP02) in the field of the galaxy NGC 720 and one (IXO5) around NGC 1073.

## 2. Observations and data reduction

We found probable optical counterparts in the Digital Sky Survey (DSS) plates for objects IXO1 and 2 around NGC 720 (the existence of the optical counterparts of these two objects was pointed out by CP02) and IXO5 around NGC 1073. Figure 1 shows DSS plates centered on NGC 720 and NGC 1073, and the position of the possible optical counterparts of the IXO objects. We obtained long-slit spectroscopy of these three objects with the WHT<sup>1</sup> on 28-29 Dec. 2002. We used the red arm of the ISIS spectrograph with the grism R158R. The slitwidth was 1 arcsec. This provides a sampling of  $1.62 \text{ \AA pixel}^{-1}$  and a resolution of  $8 \text{ \AA}$ . For each object we took a single image with a exposure time of 1800 sec. The data were reduced using IRAF<sup>2</sup>. Further details of the observing conditions and data reduction can be found in López-Corredoira & Gutiérrez (2003).

The extracted spectra of the three objects are presented in Figure 2. All of them are emission line objects. It is evident from the optical spectra that objects IXO1 and IXO2 around NGC 720 are normal appearing quasars. From the main spectral features indicated in Figure 2, we obtain redshifts of  $z = 2.216$  and  $z = 0.964$  for IXO1 and IXO2 respectively. Given the paucity of quasars and the fact these have strong X-ray emission, we think the identification of these objects is unequivocal.

The optical object that we have identified with IXO5 has strong narrow emission lines. From the position of the main lines we measure a redshift of  $z = 0.0040$  or in velocity  $1200 \text{ km s}^{-1}$ . According to the ratio of  $\text{OIII}(5007)/\text{H}\beta$  and  $\text{H}\alpha/\text{NII}(6584)$ , this object should be a HII region. Its redshift is similar to that quoted in NED for the galaxy NGC 1073 and it is in a region close to one of the spiral arms. The abundance of HII regions in the spiral arms makes the identification of the optical counterpart of the X-ray emission not as clear as for the objects IXO1 and IXO2 (furthermore there are a much fainter optical sources near this HII region as can be seen in Figure 1). In any case, if the identification is correct, IXO5 would be associated with ionized gas, with the X-ray photons of the ULX as the possible source of ionization. Gao et al. (2003) have found more than a dozen of ULX's apparently associated to the outer, active star-forming ring in the Cartwheel ring galaxy.

## 3. A compilation of ULX's identified as quasars

In Table 1 we present a compilation from the literature of objects which fit the definition of ULX's and have been spectroscopically identified. Three of the objects (the ones

denoted as IXO1, 2 and 43) are listed as ULX's in CP02. The rest of the objects, although they fit the observational criteria of classification as ULX, were not included in the above catalog apparently because they were known quasars with higher redshift than the parent galaxy. The parameters quoted in this table are:

Column 1: The designation ULX (or IXO in the CP02 catalog) is based on a  $\log L_X \geq 38.5 \text{ erg s}^{-1}$  as estimated in Col. 5.

Column 2 and 3: The Right Ascension and declination of each object (epoch 2000).

Column 4: The X-ray counts/ks measured whenever possible from the ROSAT HRI detector in order to match as closely as possible the CP02 flux criteria. In a few cases outside the HRI field they were estimated from PSPC observations.

Column 5: The X-ray luminosity ( $\log L_X$ ) if the ULX's are at the same distance as the associated low-redshift galaxies (see discussion below). If the ULX's were not at the same distance, the real luminosities would have to be multiplied roughly by  $\left(\frac{d_{\text{ULX}}}{d_{\text{galaxy}}}\right)^2$ . Except for the IXO's, most of these values have been calculated by the relation between the HRI counts/ks and the CP02 luminosities.

Most of the galaxies have redshift  $0.003 \leq z \leq 0.005$  where the contribution to this redshift from their peculiar velocities could be significant. Therefore, except for NGC 720, NGC 4168 and NGC 4258 the distances used for the ULX's in Table 1 are the distance to the associated Local Supercluster, 15.3 Mpc. (Hubble Key Project, Freedman et al. 2001). The flux calculations vary somewhat from hard to soft bands and the raw counts are subject to variability in most sources. We have only attempted to get the calculated luminosities approximately on the scale of other catalogs.

Column 6: The redshift ( $z_Q$ ) measured for the object which has been optically identified with the X-ray source.

Column 7: The apparent magnitude is in the V band but in a few cases in other bands as individually noted in Véron-Cetti and Véron (2000).

Column 8 and 9: The name and redshift ( $z_G$ ) of the host or parent galaxy.

Column 10: The radial distance ( $r$ ), in arcmin, from the center of the galaxy to the position of the ULX. This usually is about 4 - 5 arcmin for IXO identifications but we have included a few here with slightly larger acceptance distances as individually noted.

Column 11: The absolute optical magnitude (see above note in column 7).

Column 12: A note to indicate BL Lac type objects.

Column 13: References

### 3.1. Comments on Individual objects

- NGC 720: These two IXO's lie very close to a bright ( $B_T = 11.15 \text{ mag}$ ) E galaxy. The galaxy is a very strong ROSAT X-ray source which emits 148 cts/ks. Moreover, there is a strong, "twisted", X-ray

<sup>1</sup> The William Herschel Telescope (WHT) is operated by the Isaac Newton Group and the IAC in Spain's Roque de los Muchachos Observatory.

<sup>2</sup> IRAF is the Image Reduction and Analysis Facility, written and supported by the IRAF programming group at the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona.

jet/filament which curves southward as it emerges from the nucleus (Buote and Canizares 1996). In addition to the two ULX's, X-ray quasar candidates of similar apparent magnitude are conspicuous at larger radial separations from NGC 720 (see "Catalogue of Discordant Redshift Associations", Arp 2003).

- NGC 1073: In the CP02 catalog there are two X-ray sources in this galaxy which are at about the same distance from the nucleus and much brighter in X-rays than the source which they designated IXO 5 (this is associated to a HII region if our identification was correct, as said). These two were not include in the IXO CP02 catalog because it was known that they were quasars (Arp and Sulentic 1979; Burbidge et al. 1979). But clearly these fit the definition of ULX's and are listed in Table 1. Also included in Table 1 is the third known quasar in NGC 1073 since it has  $\log L_X = 38.7$  erg s<sup>-1</sup> only slightly above the general criterion for ULX's. The strong X-ray quasar with  $z = 1.411$  is also a strong radio source. Since high redshift compact objects which are strong in both X-ray and radio are generally now regarded as BL Lac type objects it is noted in the last column of Table 1.
- NGC 1365: This is a well known Seyfert Galaxy in the Fornax Cluster. About 12 arcmin to the SE in the direction of its extended spiral arm lies a very strong X-ray BL Lac (Arp 1998, p. 49). The distance to the Fornax Super Cluster is about the same as to the Virgo Super Cluster in the opposite direction in the sky, or about 15 Mpc (or see Arp 2002 for a Cepheid distance of 18 Mpc). With this distance to NGC 1365, the BL Lac object comes within the acceptance radius of the IXO Catalog and is included in Table 1.  
Closer in radial separation on the other side of NGC 1365 is a strong X-ray source with  $z = 0.904$  (La Franca et al. 2002).
- NGC 3628: This starburst/low level AGN exhibits extensive outgassed plumes of neutral hydrogen and is apparently ejecting X-ray material along its minor axis. Point X-ray sources might be associated with this ejected material and a number have already turned out to be quasars (Arp et al. 2002). We lists 7 of these quasars which have  $\log L_X$  between 38.8 and 39.6 erg s<sup>-1</sup>. Column 10 shows that six of these quasars fall within the same radial distances as most of the ULX's in this Table. The seventh, which has the strongest,  $\log L_X = 39.6$  erg s<sup>-1</sup>, falls at a greater distance, very similar to the radial distance of the bright BL Lac from NGC 1365.
- NGC 4151: There is a powerful X-ray source only 4.9 arcmin N of this active Seyfert galaxy. It is also a strong radio source (de Ruiter, Arp, Willis 1977) but, surprisingly, quite faint optically. Later it was shown that there was an X-ray filament apparently linking this  $z = 0.615$  BL Lac quasar to the nucleus of NGC 4151 (Arp 1997, Fig. 17). The object should have been included in the CP02 catalog but they centered their field to the SW of NGC 4151, just leaving

it out of their frame. As a result this important BL Lac object was not listed as an IXO.

A very interesting object SW of NGC 4151 was, however, listed as IXO 43. It turns out to be a galaxy on the end of a chain of seven or eight galaxies (Arp 1977). This end galaxy on the chain has an emission spectrum of about  $z = 0.239$  and is apparently the identification of the Ultra Luminous X-ray Source (IXO 43). Three other members of the chain have redshifts near  $z = 0.160$  and there are indications of absorption redshifts of  $z = 0.04$  to  $0.06$ .

- NGC 4168: A faint AGN galaxy at redshift  $z = 0.217$  is the ULX close to this Seyfert 1 galaxy which has  $z = 0.0076$  (Masetti et al. 2003). It is similar to the objects found in the filament from the Seyfert NGC 7603 (López-Corredoira and Gutiérrez 2002, 2003). Masetti et al. title their paper "Yet another galaxy identification for an ultraluminous X-ray source".
- NGC 4203: A remarkably similar object to the  $z = 0.615$  BL Lac object near NGC 4151, is the strong X-ray source only 2.1 arcmin from NGC 4203. It has a redshift of  $z = 0.614$ . This is another source which was not included in the CP02 catalog due to previously known high redshift.  
NGC 4203 is a liner type AGN with broad Balmer lines. It is also a strong X-ray source and an IRAS infrared source. IXO 45 is just W of the BL Lac, Tonanzintla 1480, and optically identified with a blue quasar candidate. Chandra snapshots of this field show the galaxy X-ray emission and the strong emission of the adjacent ULX's (Terashima and Wilson 2003).
- NGC 4258 is a Seyfert II galaxy with "anomalous" spiral arms. The distance used to compute the X-ray emission is 6.4 Mpc. More details can be found in Vogler & Pietsch 1999.
- NGC 4319: This is an unusually disrupted spiral with a well known quasar/AGN, Markarian 205, only 40 arc sec south of its nucleus. As Table 1 shows this ULX is exceptionally strong in X-rays, the strongest in the Table at  $\log L_X = 41.5$  erg s<sup>-1</sup>, if it were at the redshift distance of NGC 4319, and much larger luminosity if the redshift were cosmological.
- NGC 4374: This is a large radio galaxy. The close X-ray source has long been known as a quasar of  $z = 1.25$ . Again, this was not included in the CP02 catalog just because its known high redshift.
- NGC 4698: The central galaxy here is a bright nearby Seyfert 2 galaxy. Foschini et al. (2002c) identified a ULX within only 73 arcsec of the nucleus of the galaxy. If it was an object at the same distance as the galaxy it would have a luminosity of  $\log L_X = 39.5$  erg s<sup>-1</sup>. This ULX, however, turned out to be a quasar of  $z = 0.43$ . In fact it turned out to be a pure absorption line BL Lac quasar which is a very rare type of object. Its apparent magnitude was quite red,  $B = 21.3$  and  $R = 19.6$  mag. In order to get it roughly on the  $V$  system we take a mean of these and get an absolute magnitude of  $M_{abs} = -10.4$  mag, corresponding

roughly to the lower limit of the optical luminosities of the ULX/quasars in Table 1.

**Note** It is perhaps significant that almost exactly on a line through the nucleus of NGC 4698, extended beyond the BL Lac, is another, stronger X-ray source, 1RXS J124828.2+083103. It has a redshift of  $z = 0.120$ . Extended further beyond that is a line of fainter galaxies of unknown redshift (Forschini et al. 2002c). It is very similar to the lines of galaxies extending from active low redshift galaxies that were found in (Arp 2001b).

## 4. Discussion

Data available so far and compiled in Table 1 indicates that at least an important fraction of the ULX's are quasars. However, there is one respect in which the ULX quasars are different from the general run of quasars. Out of the 10 galaxies listed in Table 1, six have strong BL Lac objects associated with them as ULX's. A further case was recently discovered: in a recent Chandra investigation of the multiple interacting nuclei of NGC 4410 a possible population of ULX sources were investigated. Nowak et al. (2003) reported: "One of these sources is clearly associated with a radio point source, whereas another source (in fact the brightest in the system), may also be associated with radio emission".

### 4.1. Excess of X-ray quasars around active galaxies

A first observation is that almost every one of the galaxies which have associated ULX's in Table 1 are Seyfert, starburst, radio or AGN active galaxies. One might argue that these are selectively the most X-ray observed class of galaxies, nevertheless it is striking that there is not even one, normal quiescent galaxy among the group. A systematic study of the kinds of galaxies most associated with quasars and ULX's would be useful. Apparently this is in disagreement with the paper by Humphrey et al. (2003) which states that they found, with Chandra, 22 ULX's in a sample of 13 *normal* galaxies. However the 7 galaxies from which those 22 ULX's actually come, include a Liner/AGN, a Seyfert, an X-ray cluster, an interacting radio X-ray pair (Arp 281) and a strong radio ejecting galaxy in the center of the Fornax Cluster (NGC 1399). For their five least active galaxies only one candidate ULX was found. So, it seems that in fact the active galaxies do preferentially produce the ULX's.

In their study of X-ray sources in fields around bright Seyfert galaxies, Radecke (1997) and Arp (1997) showed that there was an overdensity of bright, point X-ray sources compared to control fields at a significance level of  $7.5\sigma$ . According to the present paper, these X-ray sources consistently turn out to be mostly quasars of a normal range in redshift. The radii from the central galaxy within which these X-ray quasars were found was roughly 5 to 50 arcmin (from the outer edges of the galaxies to the field limit of the PSPC, ROSAT detector). In the present case

of the ULX's, the majority are found within about 5 arcmin of the central galaxy. Roughly speaking, there is a difference of about 100 in the areas concerned so that the chance of finding unrelated background sources is roughly 1/100 of the probability in the larger area in which the  $7.5\sigma$  association was found. When some ULX's turned out to be much higher redshift, each of these was relegated, on an individual basis, to be a background source. Now, however, we have about 20 cases, all turning out to be quasars but not one with a binary stellar spectrum.

Of the 24 Seyferts investigated in Radecke (1997) and Arp (1997) only four had BL Lac's associated. But it should be noted that those BL Lac's were the most significant associations with the surveyed active galaxies. Just by themselves the chance of finding those four was  $2 \times 10^{-9}$ . Here in Table 1 we see two of those previous BL Lacs (with NGC 1365 and NGC 4151) but in addition, four new ones, four of which are extremely close, between 2.1 and 1.2 arcmin of the host galaxy so the probability to have them as background sources is much lower. The question then is: why would BL Lacs be more closely associated than ordinary quasars with Seyfert, starburst, radio or AGN galaxies?

### 4.2. Very bright, off nuclear, Chandra ULX's

Active galaxies like NGC 3628, Arp 220 and M 82 are now known to have very bright, ULX sources very close to their nuclei. Because these are generally even more X-ray luminous than the ones discussed here it would be especially important to attempt optical identifications with high resolution telescopes. For instance in NGC 3628 a source  $\log L_X = 40$  only 20 arcsec from the nucleus is reported as violently variable (Strickland et al. 2001). Arp 220 has a source  $\log L_X = 40.6$  erg s $^{-1}$  only 7 arcsec off nucleus (Clements et al. 2002). NGC 7319, the Seyfert Galaxy in Stephan's Quintet has a ULX only 8 arcsec S of its nucleus (Trinchieri et al. 2003); it is identified with a stellar appearing object at  $B = 21.78$  mag (Galianni & Arp in preparation). M 82 has its most luminous X-ray source variable between  $\log L_X \sim 40$  to 41 erg s $^{-1}$  (Matsumoto et al. 2001) lying within 8 arcsec of the M82 nucleus, but no optical identifications have been made so it can only be surmised that it would turn out to be like, or a precursor of, the ULX's for which we have spectra in the present paper.

### 4.3. Possible interpretation

Arp (1987,1998) suggested that quasars emerge from the nuclei of galaxies. In that model the quasars or proto quasars must pass out from the nucleus and out through the body and immediate environments of the galaxy before arriving at the distances where they have been shown to be physically associated. In this case they must pass through the region in which the present ULX's have been identified. It was therefore *predicted* that we should ob-

serve quasar-like objects in just the region in which observers are reporting ULX's (see Burbidge, Burbidge and Arp 2003a). Seyfert, starburst, radio or AGN active galaxies would be the parent ejecting galaxies. Rare cases such as the ULX in NGC 4698 (see Table 1), where there are no optical emission lines would represent a recent or strong internal burst or external interaction which removed even the usual gaseous, optical emission regions leaving only the core of absorption line stars. This model also gives a possible evolutionary connection between recent observations of HII and other narrow line galaxies and the ejection of quasars. Several high or medium redshift emission line objects apparently emerging from low redshift active galaxies either in or entraining luminous filament/arms are given in the literature: NGC 4151 (Arp 1977, 2003), NGC 1232 (Arp 1982, 2003), NGC 7603 (López-Corredoira & Gutiérrez 2002, 2003), NEQ3 (Arp 1977, Gutiérrez & López-Corredoira 2003), NGC 1365 (Roy & Walsch 1997), NGC 3628 (Arp et al. 2002), 53W-003 (Arp 1999b), NGC 2639 (Arp, Burbidge and Zibetti, A&A submitted), etc. Many of these systems are known to have ULX's. Obviously deeper multi-color images and Chandra<sup>3</sup> X-ray observations should yield important results on all of these objects.

Another suggested explanation for these association of galaxies and quasars with different redshift is mesolensing by King objects. In López-Corredoira & Gutiérrez (2003) this is discussed in more detail.

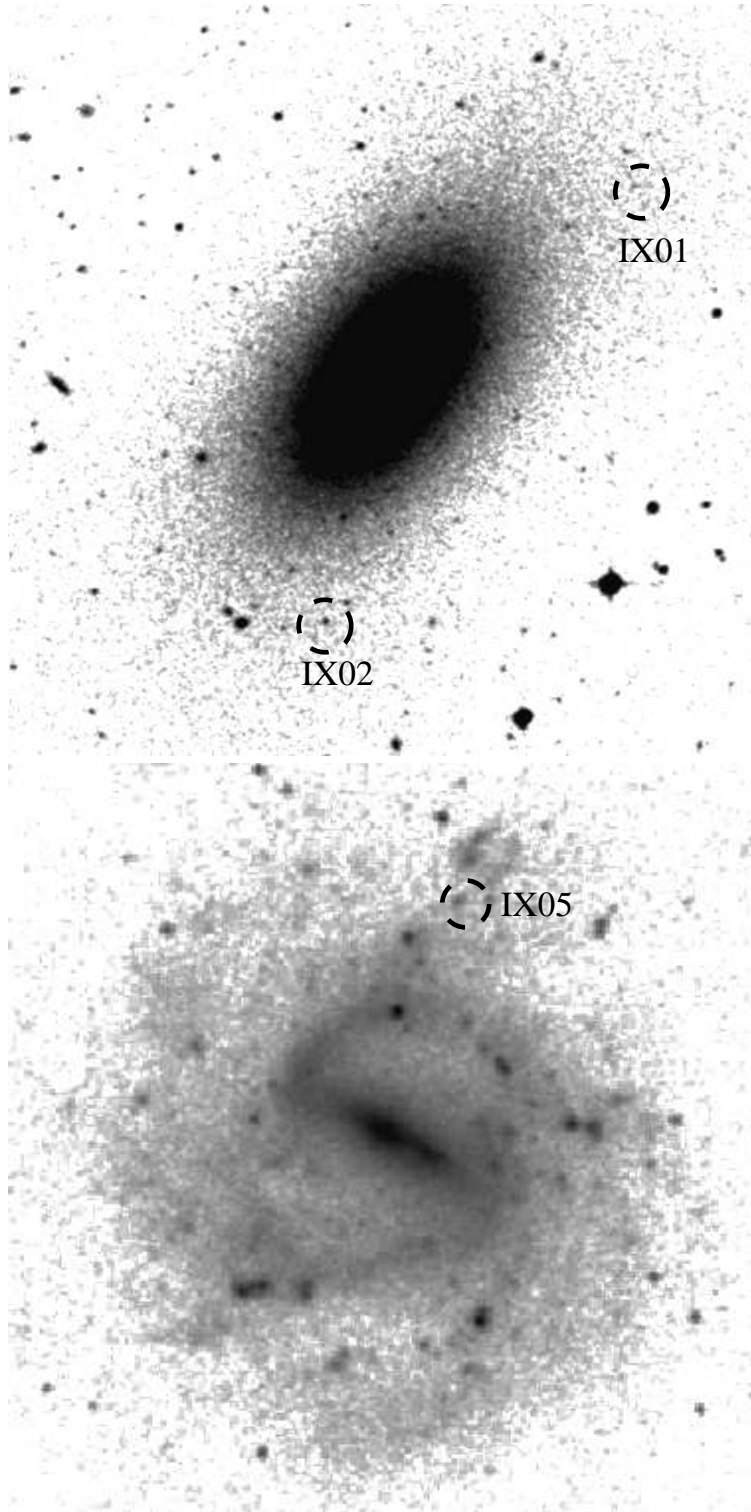
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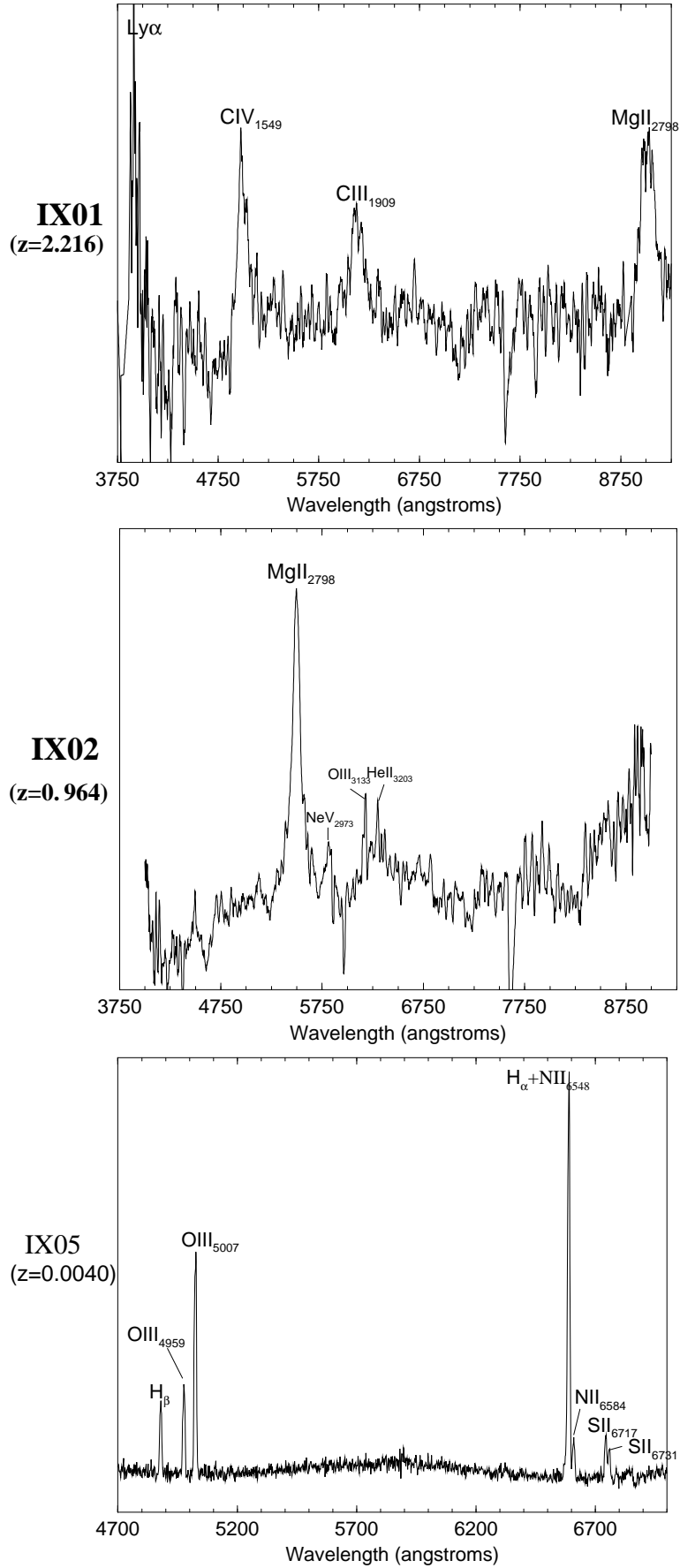
<sup>3</sup> It must be noted, however, that an application to make an observation of NGC 7603 with Chandra was turned down; as a consequence we do not know if the two HII galaxies in the bridge are X-ray sources nor do we know what else this active Seyfert contains.

ID	RA (hh mm ss)	Dec (deg mm ss)	cts/ks	log ( $L_X$ )	$z_Q$	mag	Host galaxy	$Zz_G$	r (arcmin)	$M_{\text{abs}}$	Type	Refs.
IXO1	01 52 49.7	-13 42 11	0.50	39.1	2.216	20.6	NGC 720	0.006	3.4	-11.3	...	1
IXO2	01 53 02.9	-13 46 53	1.77	39.7	0.964	19.2	...	...	2.7	-12.7	...	1
ULX	02 43 39.4	01 21 09	1.2	39.2	1.400	20.0	NGC 1073	0.004	1.4	-10.9	BL Lac	2
ULX	02 43 39.5	01 22 20	0.4	38.7	1.945	19.8	...	...	1.8	-11.1	...	2
ULX	02 43 33.3	01 21 36	3.0	39.6	0.599	18.8	...	...	2.1	-12.1	...	2
ULX	03 34 07.1	-36 04 00	3.6	39.8	0.904	19.7	NGC 1365	0.005	7.7	-11.2	...	3
	03 33 12.2	-36 19 48	38.8	40.9	0.308	18.0	...	...	12.4	-12.9	BL Lac	3
ULX	11 20 14.7	13 32 28	0.83	38.8	0.995	20.1	NGC 3628	0.003	3.0	-10.8	...	4
	11 20 11.9	13 31 23	1.39	39.0	2.15	19.5	...	...	4.2	-11.4	...	4
	11 20 06.2	13 40 24	2.50	39.3	0.981	19.2	...	...	5.5	-11.7	...	4
	11 20 39.9	13 36 20	0.83	38.8	0.408	19.6	...	...	5.6	-11.3	...	4
	11 20 41.6	13 35 51	0.83	38.8	2.43	19.9	...	...	6.0	-11.0	...	4
	11 19 46.9	13 37 59	1.67	39.1	2.06	19.6	...	...	7.9	-11.3	...	4
	11 21 06.1	13 38 25	6.11	39.6	1.94	18.3	...	...	12.3	-12.6	...	4
IXO43	12 10 07.9	39 23 12	0.88	39.3	0.239	18.4	NGC 4151	0.003	5.0	-12.5	...	5
	12 10 26.7	39 29 09	63-106	40.6-41.9	0.615	20.3	...	...	4.9	-10.6	BL Lac	5
ULX	12 12 14.6	13 12 48	4.0	39.4	0.217	18.7	NGC 4168	0.0076	0.75	-13.9	...	6
ULX	12 15 09.2	33 09 55	38.4	40.7	0.614	17.5	NGC 4203	0.004	2.1	-13.4	BL Lac	7
ULX	12 19 23.6	+47 09 38	3.9	38.9	0.398	20.4	NGC 4258	0.0015	8.6	-8.6	...	8
ULX	12 21 44.0	75 18 38	255	41.5	0.071	15.2	NGC 4319	0.005	0.7	-15.7	BL Lac	9
ULX	12 25 12.0	12 21 53	5.6	39.8	1.25	18.5	NGC 4374	0.004	2.4	-12.4	...	10
ULX	12 48 25.9	08 30 20	...	39.5	0.43	18.9, 21.9	NGC 4698	0.003	1.2	-12.0, -9.0	BL Lac	11

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**Fig. 1.** DSS plate centred on NGC 720 and NGC 1073 with field of views of  $5' \times 5'$ . Indicated are the positions of the optical counterparts of the objects IX01, IX02 and IXO 5. See main text for the details.



**Fig. 2.** Spectra measured with the W. Herschel telescope of the ULX called IX01, IX02, IX05 in the Colbert and Ptak Catalog (2002). The vertical axis is the instrumental flux in arbitrary units.